California Tank Vessel Escort Program for the Los Angeles/Long Beach Harbors
Tank Vessels up to 420,000 Displacement Tons

Prepared for California Office of Spill Prevention and Response

The Los Angeles Long Beach Harbor Safety Committee
June 2010

The Need for a New Tug Escort Regulation in Los Angeles/Long Beach Harbor

Introduction

The goal of this project is two-fold. First, the existing Tank Vessel Escort Program Force Selection Matrix (the "existing matrix")[1] for the Los Angeles and Long Beach Harbors needs to be extended to include bollard pull requirements for tank vessels with displacements greater than 340,000 long tons,[2] which is the upper limit of the existing matrix. Second, that portion of the existing matrix applicable to tank vessels with displacements from 260,000 to 340,000 long tons must be evaluated for water depths as low as 1.1 x draft (i.e., 10% under-keel clearance).[3]

The existing matrix needs to be extended upwards because larger tank vessels are expected to call at the twin ports of Los Angeles and Long Beach. Recently completed channel deepening projects have increased the controlling depths in both harbors to accommodate larger tank vessels. Also, a new crude oil delivery terminal in Los Angeles outer harbor will be constructed to accommodate Very Large Crude Carriers (VLCC's) up to 380,000 long tons displacement.

As part of the proposed matrix extension, the bollard pull requirements for tank vessels operating on water depths less than 1.2 x draft need to be revisited. The ship simulation program used to develop the existing matrix was based on ship modeling performed in water depths equal to 1.2 times draft. However, the larger VLCC's calling at the ports of Los Angeles / Long Beach may operate with an under-keel clearance as low as 1.1 x draft, which could affect tank vessel handling characteristics.

[1] The regulations for the Tank Vessel Escort Program for Los Angeles Long Beach Harbors are contained in Title 14, California Code of Regulations (14 CCR) §851.20 – 851.32. The Force Selection Matrix is at 14 CCR 851.27, Tanker and Tug Matching Criteria.

[2] All tank vessel displacements described in this document are expressed in units of long tons where one long ton is equal to 2,240 U.S. pounds. For the sake of comparison, one long ton is equal to 1.016047 metric ton.

[3] The Los Angeles and Long Beach Harbor Safety Plan allows escorted tank vessels to operate in water depths equal to 1.1 times draft, which is commonly referred to as "10% under-keel clearance."

Background – Development of the Existing Matrix

The current tank vessel escort regulation, enacted in the mid 1990's, allows the use of both conventional and tractor tugs to perform tanker escort work. It provides for only one tug positioned aft on the transom. If that single aft tug cannot meet the total bollard pull requirement as prescribed in the existing matrix, a second tug may be placed forward to compensate for the bollard pull short-fall. Nonetheless, because of the reduced effectiveness of a forward tug, the second tug must meet a higher pull requirement.

When the existing matrix was developed, it was reasoned that if an escort tug(s) had the bollard pull necessary to stop and turn a disabled tank vessel according to an agreed criteria,[4] then that same tug(s) would have sufficient power to safely manage a similar size vessel during any reasonably foreseeable failure scenario. The SHIPMAN[5] ship maneuvering simulation program was then used to determine how much power a tug would need to stop and turn various sized tank vessel models. Using the resultant data, a force selection matrix was developed that matched tug pulling power to various tank vessel sizes.

The current regulation was originally enacted 15 years ago when conventional tugs and smaller, less efficient tractor tugs[6] populated our resident harbor tug fleet. The current regulation allows conventional tugs to escort tank vessels without being tethered. Greater bollard pull requirements were factored into the force selection matrix to counterbalance the lag times and other operating restrictions associated with those less capable tug assets.

Additionally, "team towing"[7] was not a fully developed practice in the mid-1990's, so the current regulation does not allow two tugs to work aft in tandem, which is sometimes necessary to meet the higher bollard pulls required on larger tank vessels. The current regulation requires a second tug positioned forward to make up the single aft tug's power shortfall. Recognizing that a tug positioned forward is less effective, the existing matrix uses a multiplier to ensure the forward tug has sufficient power. For example, on some larger vessels, the existing matrix requires a 50-ton[8] tug on the bow to compensate for a 10-ton shortfall at the stern.

---

[4] The existing matrix is based on data obtained from simulating the following maneuvers:

- Turn a ship, traveling at an initial speed of 5 knots, 47º to port within a 4,000-foot (1,220m) head reach limit.
- After completing the turn, stop the ship from a minimum of 4 knots within a 4,000-foot (1,220m) head reach limit when the tractor type tugs are employed because the speed will decrease while turning.
- For simulations, tethered tractors are to use a standard 15 second failure recognition/response time delay and a 30-second ramp up to full power.
- The Harbor Safety Committee rules restrict the number of escort tugs to two in the LA/LB complex.

[5] Glosten Associates, Inc. developed and provided the SHIPMAN ship maneuvering simulation program.

[6] Many of the older tractor tugs had rated bollard pull less than 40 tons.

[7] *Team Towing* is the practice of running two tugs in tandem on aft leads.

[8] All tug boat bollard pull ratings described in this document are expressed in units of short tons where one short ton is equal to 2000 U.S. pounds.

Under-keel Clearance Considerations

The California Office of Spill Prevention and Response recently expressed concern because the SHIPMAN program that was used to develop the existing force selection matrix was based upon modeling that used 20%-of-draft under-keel clearance. While that shipmodeling is sound in many circumstances, it is not consistent with the Los Angeles and Long Beach Harbor Safety Plan's best marine practice that allows vessels to operate in water depths affording 10%-of-draft under-keel clearance. Because smaller under-keel clearances are known to affect a ship's behavior and handling characteristics,[9] the California Office of Spill Prevention and Response has recommended that the existing force selection matrix requirements be evaluated for VLCC's operating in water depths equal to 1.1 times their draft.

This evaluation can be limited to tank vessels with displacements equal to or greater than 260,000 long tons because tank vessels with lesser displacements will necessarily have 20% under-keel clearance in all areas that require a tug escort in the ports of Los Angeles and Long Beach.[10]

[9] Typically a ship becomes more difficult to turn as under-keel clearance is reduced.

[10] In Long Beach harbor the controlling depth is 76 feet. Tank vessels up to 63'04" draft would have 20% under-keel clearance at Mean Lower Low Water (MLLW). In Los Angeles outer harbor (the only area in LA harbor that will have a deep-draft tank vessel berth) the controlling depth is 81feet. Tank vessels up to 67'06" draft would have 20% under-keel clearance at MLLW. Tank vessels with displacements less than 260,000 long tons will necessarily carry at least 20% under-keel clearance in both harbors. For example, the 310,000 dwt class tank vessel British Pride draws less than 61 feet when its displacement is 260,000 long tons.

Proposal for a New Tug Escort Regulation for Los Angeles / Long Beach Harbors

Modern Tug Fleet Affords an Opportunity for Improvement

The resident ship assist tug fleet in the Los Angeles and Long Beach Harbors has undergone a significant change during the past 15 years. Conventional tugs have been replaced with more versatile tractor tugs. The majority has at least 45 tons bollard pull and some are rated upwards of 65 tons. Additionally, we have developed improved methodologies and practices that better utilize our modern tug assets. For example, we have demonstrated that "team towing" is a reliable practice and should be incorporated into new rulemaking.

New Tug Utilization Requirements

The Los Angeles Long Beach Harbor Safety Committee recommends that in addition to extending and reevaluating the existing matrix, the regulation be revised so that it better reflects modern tugboat practice and requires the use of improved equipment. The committee recommends:

- Only tractor tugs should be allowed to perform tanker escorts. This provision will eliminate the "Conventional Tug" portion of the existing matrix.

- Tugs with sufficient bollard pull to satisfy the matrix force requirement should be positioned aft on the transom. This provision will eliminate the need to maintain the "2nd tug ratio" feature in the existing matrix.

- All tugs required under the regulation must be tethered.

The Los Angeles Long Beach Harbor Safety Committee recommends that the California Office of Spill Prevention and Response enact new regulations for the California Tank Vessel Escort Program For Los Angeles Long Beach Harbors and adopt new **"tug utilization requirements"** as follows:

Any tug employed to meet the bollard pull requirement in the Force Selection Matrix shall:

1. Be a tractor tug.
2. Have a pulling power[11] as follows:
    - Laden tank vessels with displacements less than 180,000 long tons must employ at least one tug that satisfies the matrix force requirement.

[11] Ahead forces for tugs using stern lines, e.g., Voith-Schneider propeller (VSP) tugs. Astern forces for tugs using headlines, e.g., azimuth stern drive (ASD) tugs.

- Laden tank vessels with displacements equal to or greater than 180,000 long tons must only employ tugs with bollard pull ratings of 45 short tons or more.

3. Be positioned on an aft lead.[12]
   - A single tug may be used on an aft lead to satisfy the matrix force requirement, or
   - A team towing configuration on aft leads may be used to satisfy the matrix force requirement, provided that no individual tug used in a team towing configuration is rated at less than 45 tons bollard pull.
4. Be tethered prior to the tank vessel reaching the following positions:

   Long Beach
   - For tank vessels with a "static deep-draft"[13] that is less than or equal to 16.5 meters (54' 01") – all tugs required under this regulation must be tethered before the tank vessel passes the LB Sea Buoy.
   - For tank vessels with "static deep-draft" greater than 16.5 meters (54' 01") – all tugs required under this regulation must be tethered before the tank vessel is within 1.5 miles south of the Long Beach Sea Buoy.

   Los Angeles
   - For tank vessels with a "static deep-draft" that is less than or equal to 14.0 meters (45' 11") – all tugs required under this regulation must be tethered before the tank vessel is within 2.0 miles of the federal breakwater.
   - For tank vessels with "static deep-draft" greater than 14.0 meters (45' 11") – all tugs required under this regulation must be tethered before the tank vessel is within 4.0 miles of the federal breakwater.

These new tug utilization requirements will require more capable tug assets, simplify the practical application of the new regulation, and form the basis of the revised and extended force selection matrix. Better compliance and elevated safety for all tank vessel escorts should result.

[12] Bow tugs might be required to assist during docking and as an additional escort tug on larger, deeper tank vessels, however, the tugs necessary to satisfy the minimum force requirement from the matrix must be positioned at the stern on an aft lead. Because the make-up of our harbor tug fleet has changed, and because of the advantages associated with the proven practice of team towing, tractor tug(s) tethered in the aft position will be able to stop a disabled tank vessel more quickly and turn it in either direction without depending on less effective bow tugs. This will eliminate the use of a bow tug to make up any bollard pull shortfall and discontinue the second tug ratio calculation allowed under the existing regulation.

[13] For the purpose of these regulations, "static deep-draft" is the vessel's deepest draft in still-water conditions.

Process for Developing the Revised and Extended Tug Force Selection Matrix

The Los Angeles and Long Beach Harbor Safety Committee recommends a different approach for determining the bollard pull requirements for the revised and extended force selection matrix than that used in the 1990's. When the committee developed the existing matrix, escorting was a relatively new practice and there was scant experience to draw upon. Now, however, the committee can draw upon the collective knowledge and experience resulting from 15 successful years escorting tank vessels in and out of Los Angeles and Long Beach Harbors. Any revision to the force selection matrix should be based in large part upon that experience and knowledge.

As a starting point the committee recommends using the relevant portion of the existing matrix that remains applicable to tractor tugs employed to escort tank vessels up to 260,000 long tons displacement. That portion of the existing matrix will form the foundation of the new revised and extended matrix as follows:

Tank Vessel Displacement	**Tractor Tugs**
Long Tons	**Short Tons**
0<60,000	10
60,000<100,000	20
100,000<140,000	30
140,000<180,000	40
180,000<220,000	50
220,000<260,000	62

To simplify and standardize the Matrix, the committee recommends:

- Extending the pulling requirement for the "212K < 220K" bracket downward to capture the "180K < 212K" bracket, and
- Rounding up the pull requirements for several of the other brackets.

Because these changes require the same or greater bollard pull as contained in the existing matrix and because the tank vessels up to 260,000 displacement tons will by design necessarily operate with at least 20% under-keel clearance, no additional validation should be required for the portion of the revised matrix that has been carried over from the existing matrix.

Next, the committee recommends extending the applicable parts of the existing force selection matrix to cover tank vessels ranging from 260,000 to 420,000 long tons displacement as follows:

FORCE SELECTION MATRIX **The tug forces specified are for 'normal conditions of sea and swell.' Additional tug capability may be required during severe wind, sea, swell or current conditions.**		
Tank Vessel Displacement	**Forces For Tug(s) tethered at stern [1]**	**Tank Vessel Speed Limit [2]**
Long Tons	**Short Tons**	**Knots**
0<60,000	10	8.0
60,000<100,000	20	
100,000<140,000	30	
140,000<180,000	40	
180,000<220,000	50	
220,000<260,000	62	6.0
260,000<300,000	***75***	
300,000<340,000	***87***	
340,000<380,000	***105***	
380,000<420,000	***128***	

1 Ahead forces for tugs using stern lines (e.g., VSP tugs) Astern forces for tugs using headlines (e.g., ASD tugs)

2 The applicable tank vessel speed limit applies to all those areas in which the escort tug(s) is required to be tethered.

Rather than take an approach that seeks to discover the minimum pull necessary to perform a set of predetermined maneuvers, ***the Los Angeles Long Beach Harbor Safety Committee extended and revised the existing matrix by drawing upon our members' collective knowledge and experience to determine the appropriate tug boat configuration and pulling power that will be necessary to keep any size tank vessel in safe water at all times, regardless of the failure scenario.***

The committee further recommends using computer simulation to validate the new revised and extended Force Selection Matrix as described below.

Proposal for Validating The New Force Selection Matrix

Process

The committee has identified the reasonably foreseeable worst-case failure scenarios that might be expected to occur while a large tank vessel is under escort. The committee recommends using computer-based simulation, either fast-time or full-mission, as necessary, to demonstrate that the revised force selection matrix, as extended, prescribes adequate pulling power to keep various size tank vessels in safe water during those worst-case failure scenarios. The committee believes that any other reasonably foreseeable failure event can be safely managed with the same or less tug pulling power as will be required during these worst-case failure scenarios.

Simulation Assumptions

Environmental Assumptions

1. Calm wind[14]
2. No current, no sea, no swell
3. The water depth is always 110% of draft (10% under-keel clearance).

Ship Model Assumptions

1. The tank vessel is single screw propulsion with a standard 35° rudder.
2. “Speed Over Ground” equals “Speed Thru Water.”
3. Use initial speed equal to the maximum allowable speed as specified in the new matrix for each vessel size bracket, i.e., six knots.

Tug Assumptions

1. The required tractor tugs (VSP or ASD) are tethered to the tank vessel at the time of the failure incident.[15]
2. Line length 300 feet.
3. Operating in “direct pull” mode for all simulations. The power applied at any line angle is as per Table 1.0, “Tractor Tug Performance Assumptions,” infra.
4. Tug forces for tugs used in the team towing configuration are assumed to have an effect that is equivalent to one tug having the combined power, i.e., two 45-ton tugs in team towing are assumed to be equivalent to one 90-ton tug.
5. When more than one (1) tug is used to meet the force selection matrix, each tug shall have a minimum of 45 tons bollard pull.

[14] The winds and currents that are normally experienced in the Los Angeles Long Beach Ports are not significantly strong to materially affect a loaded tank ship. Whenever winds over the harbor area become so strong as to materially affect a loaded tank ship’s transit, ship movement jobs can be postponed until the winds subside.

[15] Note: These are the tug propulsion types currently utilized in the ports of Los Angeles Long Beach. While it is possible that different tractor tug propulsion types could be introduced in the future, because the recommended validation methodology utilizes tugs in the “direct pull” operating mode, variations in tractor tug propulsion type or hull configuration should not affect validity.

6. Reaction and ramp-up time (15s. / 30s.)
   - 15 seconds from time of failure triggers the pilot's command to the tugs
   - 30 seconds after the pilot's command to the tugs, the tugs are applying the bollard pull obtained from the "Tractor Tug Performance Assumptions."

TABLE 1.0
TRACTOR TUG PERFORMANCE ASSUMPTIONS

Tank Vessel Speed 4.0 to 6.0 Knots	
Line Angle of Outboard Tug[16]	**Direct Pull Percentage of Rated Bollard Pull**
85°	*80%*
60°	*100%*
0° (Inline)	*120%*

When tank vessel speed falls below 4.0 knots, use 100% of tug's rated pulling power at all angles.

Worst-Case Scenarios

Failure Assumptions

- The under-keel clearance is equal to 10% of the vessel's draft.[17]
- Two escort tugs are tethered center-lead aft in the "Team Towing" configuration. Each tug has a bollard pull rating that is 50% of the matrix requirement.

Failure #1) Hard Starboard Rudder Failure 4000 Feet Outside Breakwater

- The tank vessel is traveling inbound to Angel's Gate at the speed specified in Force Selection Matrix for the vessel's size.
- When the tank vessel is in a position centered in the approach channel, and with bow 4000 feet from the line of the federal breakwater, the pilot orders "hard starboard" rudder.
- Immediately after the rudder reaches the hard over position, the pilot orders "amidships." The rudder is failed at that moment and remains hard over to starboard for the remainder of the exercise. This is the exercise commencement time 00m 00s.
- After the tanker has developed "noticeable" rate of turn to starboard, but in no event later than time 00m 15s the pilot realizes the rudder has failed and

[16] Line Angle of inboard tug is 10° less except when operating "Inline" when line angle for both tugs is 0° (assumes a 70-foot spread on tug line connection to the tanker's transom).
[17] If necessary raise seabed to accomplish this, i.e., use a fictitious seabed so that under-keel clearance is always 10% regardless of model draft. This will achieve a worst-case scenario of under-keel clearance for all exercises.

orders the engine to be stopped and then orders both tugs to "direct pull full 90 degrees starboard."

- At time 00m 45s the two tugs are in position[18] applying continuous power as per the "Tractor Tug Performance Assumption" Table 1.0 above.
- Exercise continues until the tank vessel is nearly stopped or until such time as the tank vessel's movement has been satisfactorily and safely arrested and controlled (vessel's rate of turn to starboard is stopped and the vessel's heading is returned near to the channel heading).
- The tank vessel's swept path must always remain within the improved federal channel (1,200 feet wide).

Failure #2) Main Engine Failure 1500 Feet Outside Breakwater.

- The tank vessel is traveling inbound to Queen's Gate at the speed specified in Force Selection Matrix for the vessel's size.
- When the tank vessel is in a position on the approach range, and with bow 1500 feet from the line of the federal breakwater, the main propulsion engine fails. The rudder continues to function normally. This is the exercise commencement time 00m 00s.
- At time 00m 15s the pilot realizes the engine has failed and orders both tugs as necessary for channel keeping.
- At time 00m 45s the two tugs are in position[19] applying continuous power as per the "Tractor Tug Performance Assumption" Table 1.0 above.
- Exercise continues until the tank vessel is nearly stopped or until such time as the tank vessel's movement has been satisfactorily and safely arrested and controlled.
- The tank vessel's swept path must always remain within the improved federal channel.

Initial Simulation Requirements

Using fast-time or real-time computer simulation, run eight (8) simulations to prove four (4) ship-model size/speed combinations in two (2) worst-case failure scenarios. Required models are on the following displacement tonnages (long tons) for each scenario:

- 300,000 displacement tons, S.O.G. 6 knots, (2) 37-ton tugs
- 340,000 displacement tons, S.O.G. 6 knots, (2) 43-ton tugs
- 380,000 displacement tons, S.O.G. 6 knots, (2) 52-ton tugs
- 420,000 displacement tons, S.O.G. 6 knots, (2) 64-ton tugs

Provide simulation results to the Los Angeles and Long Beach Harbor Safety Committee for evaluation. If, results are satisfactory, conduct real-time simulation as described below. If results are not satisfactory, then simulation vender must be prepared to discuss matrix changes as needed to address any bollard pull shortfalls, then re-run fast time simulation as necessary to achieve a satisfactory result.

[18] Position tugs as necessary to control the tank ship.
[19] Position tugs as necessary to control the tank ship.

Real-Time Simulation Requirements

Using full-mission computer simulation, demonstrate selected failure scenarios as requested to the satisfaction of the Los Angeles / Long Beach Harbor Safety Committee, representatives of the California Office of Spill Prevention and Response, and representatives of other to-be-identified interested parties.

Documentation Required From Simulation Provider

The State of California will base rulemaking on the results of the fast-time and real-time simulation runs described above.   The simulation vendor will be required to generate a report describing the following:

- Simulation equipment (hardware and software)
- Simulation equipment (hardware and software) certification re accuracy (Lloyds, ABS, DNV, or other acceptable society)
- Methodology and underlying premises use by simulation software to differentiate vessel handling characteristics in water depths equal to 1.1 x Draft from those characteristics in water depths equal to 1.2 x Draft.
- Details of each ship model and tug model employed in the simulation exercises
    - Include SWL of bitts and chocks, which must be adequate for all loads generated in simulation
- Description of the methodologies used to validate handling characteristics of the individual ship models.
- "Tug Utilization Requirements"
- Tug Assumptions
- Ship-model Assumptions
- Environmental Assumptions
- Details of each fast-time scenario including a track-plot record for each of the maneuvers at appropriate time intervals to adequately document the ship-model's track/speed/heading and the escort tugs' (power and pull direction). This record should also include:
    - Rate of Turn
    - Rudder Position
    - Main Engine R.P.M.'s
    - Other as specified by California Office of Spill Prevention and Response
- Description of each real-time scenario as above
- A "Summary of Results" for all specified maneuvers showing the following:

EXAMPLE:

Scenario	Ship Size Displmt	Draft	Water Depth	Initial Speed	Tug Size	Meets Reqmts	Figure No.
#1	340,000	68.0 ft	74.8 ft	6 kts	(2) 43 ton	Yes	1

DRAFT